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Assessing the Income Effects of Group Certification for Smallholder Coffee Farmers: Agent-based Simulation in Uganda

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Abstract

Voluntary sustainability standards, aimed at improving the environmental, social and economic aspects of agricultural production and trade, are becoming increasingly common. The coffee sector is a prime example, where sustainability certification could improve livelihoods for poor smallholders. However, as individual production volumes are low, smallholder farmers need to cooperate in certification as a group, which makes impact assessment more complicated. Previous empirical studies, reporting premia of up to 30%, have neglected the costs associated with group certification. We explore the issue using an agent-based simulation of coffee producer organisations in Uganda, including the certification-related costs for farmers. Our results suggest that certification can have a small positive impact on participating households. But the added value of certification is substantially lower than the price premium, because of certification costs. Increasing both the membership of the producer groups and their deliveries of certified coffee are necessary to improve the rewards of certification.

Keywords: *Collective action*; *commercialisation*; *market access*; *mathematical programming*; *multi-agent systems*; *Sub-Saharan Africa*.

JEL classifications: *C61, C63, D12, Q12, Q13.*

1. Introduction

The importance of rural producer organisations (RPOs) in improving market access and assisting smallholder commercialisation in developing countries is well established (e.g. Shiferaw *et al*., 2008, 2011; Markelova *et al*., 2009; Markelova and Mwangi, 2010). One way in which RPOs serve their members is through participation

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in sustainability certification schemes for agricultural products. Farmers are expected to benefit directly from certification price premiums and better access to global markets. However, RPOs and farmers also incur additional costs of certification, associated with training, monitoring, purchasing equipment and complying with sustainability standards. Hence, the participation of smallholders in certification programmes promoting voluntary sustainability standards (VSS) will only result in livelihood improvement if the benefits outweigh both the entry and operational costs of certification programmes.

VSS have expanded rapidly in the coffee sector. Standards-compliant coffee has evolved from a niche to a mainstream product, with approximately 40% of coffee in the world being produced in compliance with VSS (Potts *et al*., 2014). A number of certification initiatives for coffee have appeared, including *Fairtrade*, *Organic*, *Rainforest Alliance* and *UTZ Certified,* among others.

However, the effects of sustainability standards and group certification on participating households and RPOs ('added value') are still obscure. Since financial data are hard to collect, empirical studies do not usually consider the costs of certification, and often lack control groups, while the majority of existing studies focus on the Fairtrade label (Kolk, 2013). There is a lack of detailed quantitative evidence of the 'net benefit' for smallholder producers, especially for newer initiatives such as UTZ Certified. Existing assessments (e.g. Kilian *et al*., 2004; Raynolds *et al*., 2007; El Ouaamari and Cochet, 2014; Potts *et al*., 2014) focus on (i) discussing certification goals and requirements qualitatively, (ii) providing the reported price premiums, or (iii) estimating the amounts of coffee produced in compliance with VSS and sold as standards-compliant.

In contrast, we use a microeconomic assessment of RPO involvement in certification for coffee in rural Uganda. We assess both existing and alternative options for certification that differ in terms of the financing of entry and operational costs, the number of farmers initially included, and the share of produce that the RPO is able to certify.

To do so, we use agent-based simulation. This approach allows a detailed assessment of existing systems, and *ex-ante* assessment of potential future options, which is either impossible or impractically expensive with other approaches. We calibrate our simulation model with detailed household data to simulate the functioning of the RPOs of coffee farmers in Uganda.

1.1. Research project

Our study was conducted as part of the international research project 'Working together for market access: Strengthening rural producer organisations in Sub-Saharan Africa,' funded by the German Federal Ministry of Economic Cooperation (BMZ) and led by the International Food Policy Research Institute (IFPRI). The aim of the overall project was to propose viable measures that could support the commercialisation and improve the income of rural farmers, and assess the impact of these measures by conducting field and virtual (i.e. computer simulation) experiments.

IFPRI conducted focus groups interviews and a baseline project survey (IFPRI, 2010) that approached RPO members and administrations in Uganda. Following up on these surveys, we carried out participatory research in Uganda involving RPO managers, regular RPO members and key informants connected with the coffee sector (Latynskiy and Berger, 2016). Based on the results of IFPRI's survey and our participatory research, we created an agent-based model to simulate the decision-making and functioning of farmers and RPOs from the Lake Victoria Crescent area of Uganda and analyse possible effects of various courses of action (e.g. engaging in group certification, organising payments 'on-the-spot', etc.) through scenario-based analysis.

1.2. Coffee market and rural producer organisations in Uganda

Coffee is the most important cash crop in Uganda and the country's main export commodity, 15% of the total value of formal Ugandan exports (BOU, 2013). In 2012, Uganda was the second largest coffee producer in Africa and the 11th largest in the world, with 310,000 hectares planted and 186,000 tons of green coffee harvested (FAOSTAT, 2016). Baffes (2006) estimated that coffee in Uganda is grown on approximately 500,000 farms. Most of these are smallholders: about 70% of coffee-growing households have less than 2 hectares of land and their livelihoods are heavily dependent on the coffee value chain (Hill, 2010). Increased value-added through sustainability certification would, therefore, affect a large proportion of the country's rural population.

The majority of coffee produced in Uganda is exported (97% in the agricultural year 2011/2012, ICO, 2015), mostly to industrialised countries. Seventy-two percent (72%) of Ugandan coffee goes to the European Union and 7% to the United States, Switzerland, South Korea and Japan (UCDA, 2014). The growing consumer demand for sustainably produced coffee (Manning *et al.*, 2012; Reinecke *et al.*, 2012; Potts *et al.*, 2014) makes VSS certification for coffee especially promising.

Ugandan market liberalisation reforms in the 1990s led to the subsequent emergence of member-owned grassroots RPOs (Mrema, 2008; Kwapong and Korugyendo, 2010). These RPOs are especially common in the coffee sector (Masiga and Ruhweza, 2007; Mrema, 2008; Kwapong and Korugyendo, 2010). They organise the collective marketing of smallholder produce, thus enabling farmers to achieve economies of scale and negotiate better prices, bypassing local middlemen. As confirmed by our field research (Latynskiy and Berger, 2016), producers are usually organised into RPOs on two levels: (i) primary farmer organisations (locally referred to as POs), which unify farmers from the same village or parish; and (ii) county or sub-county-level associations, which are usually referred to as depot committees (DCs) or area cooperative enterprises (ACEs) and are small-scale producer unions consisting of several POs from the same county or sub-county. Typically, a PO is concerned with bulking individual farmers' coffee and delivering it to a DC/ACE. The DC/ACE, in turn, collects the quantities bulked at the PO level and conducts milling and other value-added activities (e.g. quality control, sorting). In addition, the DC/ACE can be used as a platform for organising VSS certification among producer groups, since certification of low individual production volumes requires smallholders to cooperate in certification schemes as a group.

RPO members can be expected to sell their produce through a DC because a DC is able to offer higher prices due to the value added. In practice, however, not all coffee produced by RPO members is sold through a DC. From the IFPRI (2010) survey, we estimated that 48% of the coffee produced by RPO members is still sold to local middlemen. The reasons for not selling through an RPO include time preferences of the farmers, informal contract obligations, and an urgent need for cash that middlemen can all serve by paying slightly lower prices but on the spot and without delay (Latynskiy and Berger, 2016).

1.3. Costs and benefits of certification

The motivations for certification include: (i) the price premium for certified coffee; (ii) more transparent price determination, reflecting the certification traceability systems, strengthening producer bargaining positions; (iii) technical assistance increasing both quantity and quality of production; (iv) group certification leverages additional external support from NGOs to assist certification (in the case of Uganda, NGOs such as *Solidaridad*, USDAF and UDET). However, certification is hindered by the related costs for initial training, internal and external audits and standards compliance. There are also information barriers, such as limited knowledge about the certification process and the associated benefits, as well as resistance to change among potential adopters.

1.4. Case study

We focus on the *Kibinge Coffee Farmer Association* (Kibinge DC), a sub-county farmer-owned RPO in the Masaka district of Central Uganda, which is a traditional coffee-growing area. The area is characterised by favourable agro-climatic conditions for crop production (two growing seasons) and relatively good connections to input and output markets (Ruecker *et al.*, 2003). The predominant farm system is intensive coffee and banana (plantain) intercropping, where coffee is the main cash crop and plantain is the main staple crop. The farm system is semi-subsistence with very low levels of input use, and mostly relying on manual labour.

Kibinge DC markets robusta coffee and is a member of the *National Union of Coffee Agribusinesses and Farm Enterprises* (NUCAFE). In total, the Kibinge DC comprises 46 village POs and 1,716 farming households, to whom it offers a range of services, including training in good agricultural practices, the provision of planting material and transportation management (Latynskiy and Berger, 2016). Kibinge DC became involved in group certification with UTZ Certified in 2008. UTZ Certified (which started as the Utz Kapeh Foundation in 2002) is the most prominent VSS label for coffee, at least in terms of sales volume. In 2012, approximately 190,000 metric tons of coffee were sold under the UTZ Certified label, making it the largest VSS label for coffee worldwide (Potts *et al.*, 2014). The aims of this sustainability programme are to promote good farm-level production practices while supporting farm profitability, improving market transparency and product traceability.

The initial costs for certification in Kibinge DC were fully covered by NUCAFE and various other NGOs, while the DC membership covers the operational costs of certification. Initially, 450 member farmers selected from the approximately 2,000 members of the DC at the time (some households may have several members) received initial training and technical support from a UTZ consultant (Latynskiy and Berger, 2016). At the time of our research, members of the Kibinge DC were selling both conventional and certified coffee, with producer price premium for certified coffee of approximately 15%.

2. Simulation Model

2.1. Methodology

We chose agent-based simulation for our empirical assessment of group certification in Uganda. This approach has several advantages over econometric analysis (Brady *et al.*, 2009; Berger and Troost, 2014), which is commonly used for impact assessments. First, simulation models internalise consistent financial data such as cash flow and liquidity shortage, which are rarely recorded in developing countries but are needed for RPO impact assessments. Second, a large portfolio of experimental treatments (due to the low cost of computer-based experimentation) can be implemented, which allows for the testing of various certification scenarios with respect to financing and member inclusion. Assessing the same portfolio of RPO options through field experiments (e.g. randomised controlled trials) would incur prohibitive experimentation costs. Third, simulation modelling provides full control over the experiment, which is problematic to achieve in real-world experimentation, and fourth, the results of long-term treatments can be simulated *ex ante*. However, these advantages critically depend on the validity of the model structure and calibration in reflecting real conditions.

Because different households are likely to respond to treatments differently, agent-based simulation specifically incorporates the heterogeneity of farm households, implemented in the model as heterogeneous computational agents (e.g. Berger and Troost, 2014; Farrin and Miranda, 2015). The agent-based approach avoids the aggregation bias of conventional average or representative farm models and so should improve and refine the assessment of welfare effects. Data requirements, validation effort and computational demands are, however, higher than econometric modelling (Troost and Berger, 2015). In addition, agent-based land-use simulation involves substantial interdisciplinary collaboration. A project team of social and biophysical scientists was needed to develop the survey questionnaires, focus interviews, and net-map sessions jointly, as well as parameterise and validate our crop-growth simulator (Latynskiy and Berger, 2016).

2.2. *Model description*

For the technical implementation of our group certification assessment, we used MPMAS, a multi-agent software package for simulating farm household decision-making in agriculture (Schreinemachers and Berger, 2011). MPMAS was originally developed by Berger (2001) for the analysis of innovation diffusion and has been applied since then in a number of countries: Uganda (Schreinemachers *et al.*, 2007), Thailand (Schreinemachers *et al.*, 2010), Vietnam (Quang *et al.*, 2014), Chile (Berger and Troost, 2014), Ghana (Wossen and Berger, 2015) and Germany (Troost *et al.*, 2015). The model equations and software architecture of MPMAS (Schreinemachers and Berger, 2011) follow the overview, design concepts and details (ODD) protocol (Grimm *et al.*, 2010) and are not repeated here.

We developed a specific application of MPMAS,[2] parameterised using primary data from our own fieldwork in Uganda and various secondary datasets (listed in Table 1).

Two types of agents are implemented at two decision levels in MPMAS Uganda: farming household agents and an RPO agent. Household agents match the characteristics of real-world farm households, for example number of household members, available land, size of the coffee plantation, membership in an RPO, access to

[2]The MPMAS developer team has uploaded online supplementary material at https://www.uni-hohenheim.de/mas/software/UgandaSupplement.zip. The supplement contains the MPMAS software, STATA scripts, input and output files, results of cost benefit analysis, model documentation, and user manual (archive size 88 MB).

Table 1
Datasets

Model parameters	Estimation	Dataset
Soil properties	Schreinemachers *et al*. (2007)	Ruecker *et al*. (2008)
Crop growth model	Schreinemachers *et al*. (2007)	Expert knowledge, literature
Land ownership	Authors	IFPRI (2010)
Household assets	Authors	IFPRI (2010)
Labour production function (coffee)	Authors	IFPRI (2010)
Labour production function (staples)	Schreinemachers *et al*. (2007)	IFPRI (2001)
Consumption preferences	Authors	IFPRI (2010), UNPS (2010)
Livestock	Authors	UNPS (2010), UNLC (2008), IFPRI (2010), literature, expert knowledge
Population and demography	Authors	IFPRI (2010), UDHS (2007), World Bank (2012)
RPO model	Authors	IFPRI (2010), Latynskiy and Berger (2016)
Certification costs	Authors	Expert knowledge

certification, etc. The RPO agent resembles the coffee RPOs and deals with coffee marketing and all other RPO activities, including coffee delivery from its members (household agents) and group certification. The landscape is represented in MPMAS by the topographic, physical and agronomic properties of the land owned by the household agents.

The model runs in yearly time steps over a simulation horizon of 20 years. In each simulation period, farm household agents make decisions on investment, production, marketing and consumption based on their individual resource supply, natural environment and expectations. Based on these decisions, MPMAS updates the agent and landscape characteristics, simulates natural processes and implements the temporal carryover of farm assets within and between simulation periods. The agent decisions on crop management impinge on soil fertility, which in turn determines future crop yields. These data then define the future plot management of the agents. This loop of human-environment interaction and feedback is simulated in MPMAS Uganda by the Tropical Soil Productivity Calculator (TSPC), which is a biophysical simulator developed by Aune and Massave (1998) and coded inside the MPMAS software.[3]

2.3. *Agent decision-making*

The decision-making of household agents is simulated in MPMAS using mathematical programming (MP). The objective function of each agent is its expected household income, which is maximised subject to a set of constraints. The agent optimisation is formulated to reflect real-world decision-making as closely as possible. In contrast to Positive Mathematical Programming (Howitt, 1995; Röhm and Dabbert, 2003), this

[3]The integration of TSPC in MPMAS is explained in Schreinemachers *et al*. (2007).

resemblance is not achieved by adding non-linear terms to the objective function, but by disaggregating labour, land and cash requirements of agent production activities based on detailed crop calendars and by capturing individual household resource endowments and food demands of household members as well as technical constraints such as crop rotations and livestock stocking rates. We compare and test the optimal LP solutions for all real-world households in IFPRI's 2010 household survey, following McCarl and Apland (1986). Where needed, we improved association of simulated and observed results by calibrating the agent certainty equivalents pragmatically to reduce the expected returns of the more risky crops.

The decision-making of household agents in MPMAS Uganda is split into four sequential steps: investment, production, marketing and consumption. Such segmentation of decision-making is required to reflect the resource allocation and timing of activities (e.g. liquid assets that a farmer uses for long-term investment at the start of a cropping season cannot be used in production activities throughout the season). The steps are implemented by solving the individual agent MP problems recursively: optimising a particular MP problem and transferring elements of the solution vector to the MP matrix for the next step. Table 2 illustrates the four stages of agent decision-making. Each MP problem is specified so that, when making an investment decision, an agent plans for production, marketing and consumption at the same time; when deciding on production, an agent plans for marketing and consumption at the same time; and so on. The MP constraints include household resource limitations, time preferences, household subsistence requirements, crop rotations, production factor requirements, credit obligations, all at the agent-specific level.[4]

All input and output prices in our model are exogenous except for the farm-gate prices of certified and conventional coffee that result from RPO activity.[5] The decision-making and activities of the RPO agent are also simulated as an MP problem. The objective function here is the expected profit of the organisation, which is maximised subject to a set of constraints.

The RPO decision is simulated between the marketing and consumption stages of household agent decisions (Table 2). Farm agents 'send' their production, inquiries for services and membership fees to the RPO agent, which then serve as exogenous variables for the decision-making module of the RPO agent. The RPO agent in turn 'feeds' the sales prices and costs of services back to the farm agents, which influences their decision-making. Figure 1 illustrates the interaction between the two agent types as coded in MPMAS.

2.4. Agent population

In MPMAS Uganda each real-world member of the Kibinge DC is represented by one household agent in the model, and the DC itself is represented by the RPO agent.

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[4]For example, in the post-harvest decisions of an agent, the hectares of crops grown, the fertiliser applied and the credit taken are given and their values have to be fixed in the objective function.

[5]RPO output prices are exogenous when selling certified and conventional coffee to upstream traders. But RPO input prices for coffee are endogenous when buying from its members because of fixed-cost degression in RPO processing activities. Since we include local transportation costs, we finally arrive at endogenous agent farm-gate prices for certified and conventional coffee.

Table 2
Stages of household decision-making in MPMAS

Stage	Investment	Production	Marketing	Consumption
Characteristic				
Timing	Beginning of the period	Beginning of the period	End of the period	End of the period
Yields	Expected in future	Expected in current period	Actual	Actual
Resource supply	Expected in future	Expected in current period	Actual	Actual
Prices	Expected in future	Expected in current period	Expected in current period	Actual
Fixed decision variables	None	None	Land and input use, production	Land and input use, production, sales of certain crops

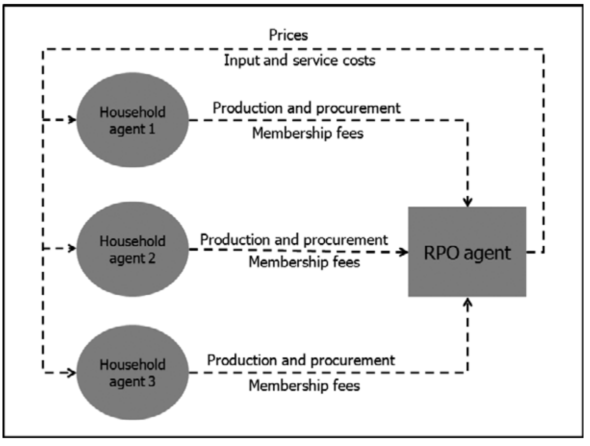

Figure 1. Interaction of agents in MPMAS
Note: This figure shows the interaction between four agents only. The MPMAS model in Uganda contains 1,716 farm household agents and one RPO agent.

The household agents in MPMAS Uganda differ from each other according to their household characteristics, resource endowments and land properties. A synthetic agent population with 1,716 households was generated from the IFPRI (2010) survey sample (n = 71 households), following the two-step approach of Berger and Schreinemachers (2006). First, a copula function was estimated to capture the empirical multivariate distribution of household characteristics in the survey sample. Second, the full number of agent profiles was then sampled from this empirical copula, using a Monte-Carlo approach. Table 3 shows the characteristics of the generated population of household agents.

The economic characteristics of the RPO agent were estimated using the membership and cost information from the Kibinge DC recorded in the IFPRI (2010) survey.

Table 3
Characteristics of farm agent population

Characteristic	Unit	Mean	Median	SD	10%	25%	75%	90%
Available land	ha	2.46	2.02	1.66	0.81	1.39	3.16	4.95
Household size	People	6.8	7.0	2.5	4.0	5.0	8.9	10.0
Labour/land ratio	People per ha	3.84	3.32	2.67	1.28	2.04	4.92	6.78
Coffee plantation	ha	1.18	0.89	0.93	0.30	0.50	1.61	2.34
Cattle owned	Heads	2.4	2.0	4.4	0.0	0.0	3.0	4.8
Goats owned	Heads	2.4	1.0	3.5	0.0	0.0	3.5	6.0
Chickens owned	Heads	11.6	0.3	19.1	0.0	0.0	18.3	34.8
Pigs owned	Heads	1.2	0.3	1.6	0.0	0.0	2.0	3.0
Livestock stocking rate	FAO unit per ha	1.00	0.59	1.54	0.07	0.25	1.16	2.27

The costs related to UTZ certification were taken from a coffee marketing study in Uganda (Latynskiy and Berger, 2016).

2.5. *Model validation*

Model validation followed common practice (Fagiolo *et al*., 2007): model outputs were compared with statistics for the respective real-world system – the agricultural system in the study area. The benchmarks for model calibration and validation were coffee yields and quantities of household crop production, which we estimated for our study area from the IFPRI (2010) project survey. We focused on coffee production while seeking to keep deviations for all other crops at an acceptable level.

Table 4 shows our simulated coffee yields compared with observed survey yields. Our MPMAS model reproduces the mean yield closely but with lower variance than in the survey, because the integrated crop-growth simulator is unable to capture the farm-specific effects of pests and diseases. These effects were introduced in the simulation as aggregate reduction factors to crop yields, which reduced the variance in the simulated yields at the household agent level. Nevertheless, our simulated coffee yields are close to the observed yields in the mean, 10th, 25th and 75th percentiles.

There is no plot- and crop-level data in the IFPRI (2010) project survey for crops other than coffee, making it impossible to compare yields of other crops, so we used crop production at the household level as a validation indicator. Figure 2 shows survey and model density functions for each of the four major crops produced (coffee, plantains, maize and beans) in the study area, which shows that the model accurately replicates crop production, especially so for coffee. Again, deviations reflect the limitations of the crop-growth simulator, which only includes pest and disease effects at the aggregate level, and the absence of plot- and crop-level data for calibration. The prediction errors for plantains are evened out at the aggregate level: the simulated mean quantity produced differs from the survey mean by only 1.5%.

To check the robustness of the model outputs with respect to the variation in initial conditions and random events, we ran the model baseline scenario 20 times, each time with a different synthetic agent population. Figure 3 reports the variation of the key model output indicators for statistically consistent landscapes and agent populations. The computed relative standard deviation for each indicator lies within a ±7%

Table 4
Validation of coffee yields

	Mean	Median	SD	10%	25%	75%	90%
Survey	1,317	954	1,154	326	584	1,621.6	2,919
Model	1,260	1,420	645	412	574	1,621.9	1673

Note: Yields of survey population are estimated from IFPRI (2010).

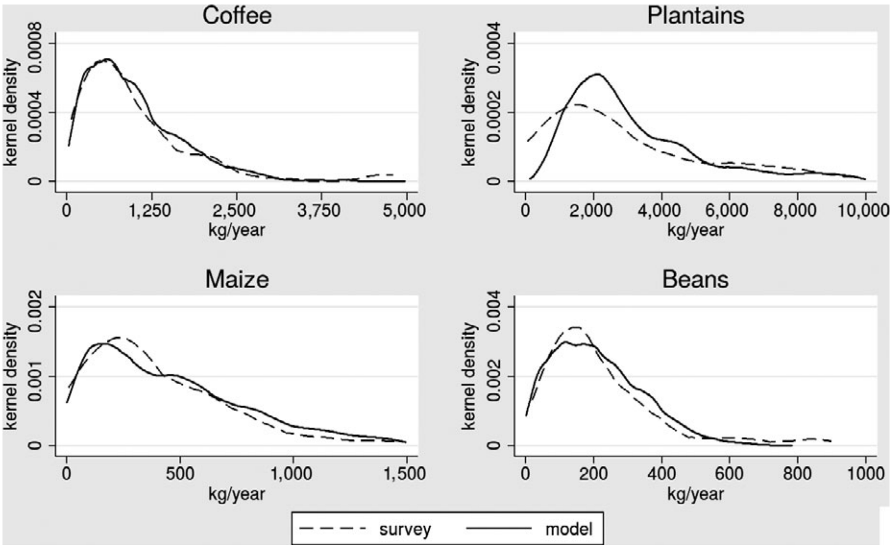

Figure 2. Model validation of crop production
Note: The graphs compare the distribution functions (by household) of the amounts produced for four major crops. Crop production of survey households was estimated from IFPRI (2010).

interval, and ±2% for our main impact indicator (agent income), strongly suggesting that the model is robust.

We also performed a sensitivity analysis of the simulation results with respect to the main model parameters (prices of coffee, agricultural input and food items, wages for hired labour, and yields of coffee and food crops). During the sensitivity analysis,[6] we evaluated the model's behaviour with respect to gradual changes in the values of the parameters as well as extreme parameter values. The model results in all cases reacted to the parameter changes consistently (e.g. an increase in coffee price led to increased amounts of coffee sales, which were judged plausible by local experts). Moreover, as will be shown below, in our scenarios for certification, we step-wise increased the key variables reflecting the certification set-up, such as the interest rate for borrowed capital. In all of these scenarios, the model responded plausibly.

[6]The results of the sensitivity analysis are reported in the online supplementary material uploaded by MPMAS developer team at: https://www.uni-hohenheim.de/mas/software/UgandaSupplement.zip. The supplement contains the MPMAS software, STATA scripts, input and output files, results of cost benefit analysis, model documentation, and user manual.

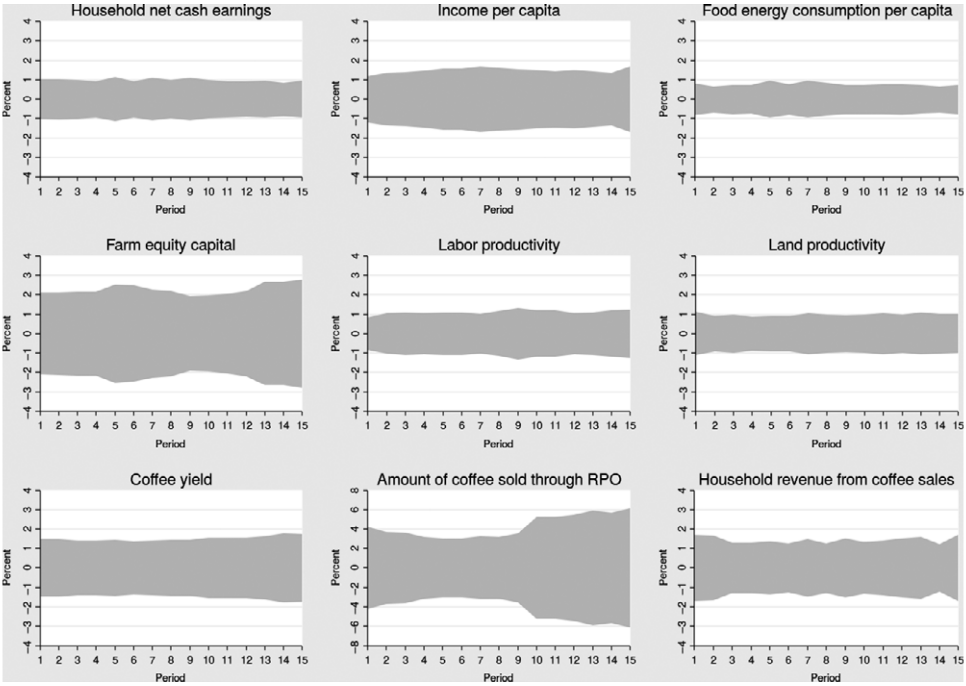

Figure 3. Model robustness to random events and variation in initial conditions
Note: Variations in the results are depicted as relative standard deviations from averages over 20 test simulations.

3. Simulation Experiments and Results

3.1. Scenarios

For the assessment of certification, we conducted a total of 60 simulation experiments (scenarios) that reflect different situations and options for certification (Table 5 provides an overview of these scenarios) plus a baseline scenario without certification. In particular, the scenarios differ by the costs that the RPO agent must bear. In the first group of scenarios, the RPO agent has no certification-related costs at all, as these costs are covered by government funding and NGOs (scenarios designated *nc*). In the second group of scenarios (prefix *rc*), the RPO agent covers only the operational costs of certification, while the costs for initial investments are funded externally. This cost-recovery arrangement is currently practiced at the Kibinge DC. In all of the other scenarios, the RPO agent must cover not only the operational costs but also the initial investment, with varying interest rates. In the third scenario (prefix *zi*), the interest rate is zero; the fourth group (prefix *fi*) has a risk-free interest rate[7] ; and the fifth group (*mi*) has a market interest rate.[8]

Our scenarios also vary the number of RPO members included in the certification programme (*mempct*<percent of members included>). In the current certification

[7]Equal to 8.5% (nominal) in 2010 for Uganda (estimated from World Bank, 2012).

[8]Equal to 19.2% (nominal) in 2010 for Uganda (estimated from World Bank, 2012).

Table 5
Codes and description of simulation scenarios

Scenario code	Scenario description	Variable value/range
nc	RPO bears no certification-related costs (costs are covered by external sources)	—
rc	RPO covers only the operational costs of certification	—
zi	RPO covers the operational costs and repays the initial investment with a zero interest rate	Interest rate (nominal) = 0% p.a.
fi	RPO covers the operational costs and repays the initial investment with a risk-free interest rate	Interest rate = 8.5% p.a.
mi	RPO covers the operational costs and repays the initial investment with a market interest rate	Interest rate = 19.2% p.a.
mempct<percent>	<percent> of RPO members included in the certification programme	Percent of members $\in$ [22; 100]
prodpct<percent>	<percent> of coffee produce that members are permitted to certify	Percent of produce $\in$ [25; 100]

scheme for the Kibinge DC, 22% of all members have been certified (i.e. *mempct22*). The scenarios also vary the share of produced coffee that the RPO members are permitted to certify (*prodpct*<percent of individual produce allowed for certification>). According to Potts *et al*. (2014), due to the oversupply of standards-compliant coffee, not all of the coffee produced in accordance with VSS can typically be sold as certified. Since we do not have data for the value of this share for the Kibinge DC, we performed multiple simulations with alternative values.

Due to the lack of more detailed empirical data related to the entry and exit of members, membership in the RPO is fixed in the simulation model – that is, the RPO agent may neither attract new members nor lose existing members. In addition, land ownership and the sizes of coffee plantations are fixed. Farm agents can change their management practices (input and labour intensity, crop mixes of food crops) and replant coffee plantations, but they cannot expand or reduce their land ownership or the areas used for coffee growing. The production costs and market prices for all products except coffee are held constant at initial levels (estimated from IFPRI, 2010). As mentioned above, farm-gate coffee prices are endogenously simulated based on the turnover and certification costs of the RPO agent. During the simulation, household agents adjust their expectations[9] with regard to coffee prices and crop yields. In all of the scenarios, the simulation model was run for 15 years preceded by four spin-up periods,[10] during which farm agents form their expectations and adjust their initial resource allocations.

[9]Using the canonical adaptive expectations formula: $EV(t) = EV(t-1) + \lambda * (AV(t-1) - EV(t-1))$, with λ for coffee prices equal to 0.5 and λ for yields equal to 1.

[10]These four extra periods at the start of the simulations are ‘dry runs’ and serve to correctly initialise the model. Therefore, their results are not considered in the assessment.

When assessing the impact of certification, we always compare one scenario with a particular certification set-up against the baseline scenario without certification. Given the robustness and consistency of the model results, we consider that a single model run for each scenario is sufficient for a valid comparison.

4. Results

The baseline simulated income distribution is relatively stable over the simulation horizon, with income increasing slightly due to asset accumulation by the model agents (figure shown in Latynskiy and Berger, 2015). The agents' baseline income distribution has the expected log-normal shape, with a small difference between the mean and the median. To assess the impact of certification, we review the differences in the means of the income distributions between the baseline scenario and the scenarios with certification.

The results of the simulation runs for certification are provided in Table 6. The table shows the economic sustainability of the certification (i.e. when sustained over 15 simulation periods and not discontinued due to negative profitability) in each simulation run (column (2)). In addition, it quantifies the mean income effect at farm household level (column (3)), the simulated added value per unit of certified coffee that members sold to the RPO (column (4)), and the change in RPO agent profits (column (5)). The income changes are reported as averages over all household agents and all 15 simulation periods. The same aggregation is performed for the added value but only considering agents that actually certified their coffee. Their added value was calculated as the difference between the price of certified coffee subtracting the per-unit certification cost and the price of conventional coffee, compared to the RPO upstream selling price for conventional coffee.[11] The reported changes in the RPO agent's profits are also average values over 15 simulation periods.

The experiments suggest sustainability (positive profitability) in all of the options in which the RPO agent does not have to repay the initial investment (*nc_* and *rc_* scenarios). In the scenarios with repayment of investment costs (*zi_*, *fi_* and *mi_*), negative profitability (i.e. non-sustainable certification) occurs: in these scenarios, the agents are only able to certify a small share of their produce (e.g. *zi_mempct22_prodpct25, zi_mempct50_prodpct25*, *fi_mempct22_prodpct25*).

The scenarios reflecting the current financing of group certification in Kibinge DC, where only the operational costs must be covered by the RPO agent and its members (*rc_*scenarios), deserve more attention. Figure 4 shows the coffee sales of the RPO agent in physical terms. Both increasing the share of certified coffee and including more members in the certification programme increases the sales of the RPO agent in physical terms (despite the increasing operational costs). At 100% certified members and 100% certified sales (*mempct100, prodpct100*) the turnover of the RPO agent increases by 135% relative to the baseline. With increasing RPO sales, the value added of certification increases despite agent time preference for immediate repayment (Table 6). In the scenarios reflecting the current inclusion of members in the certification program (*rc_mempct22* scenarios), the added value per kg of green coffee is high,

[11]The price premium does not consider the cost of certification; it is the simple difference between the member price for certified and conventional coffee. In the scenarios with no-cost certification, the price premium and the added value are therefore identical.

Table 6

Simulation results for certification

Scenario code	Arrangement sustainability[a]	Δ^b Household income, %	Member added value[c], %	Δ^b RPO profit, %
No cost certification				
nc_mempct22_prodpct25	Yes	1.3	13.3	31.2
nc_mempct22_prodpct100	Yes	4.7	13.3	85.8
nc_mempct100_prodpct25	Yes	4.2	13.3	86.2
nc_mempct100_prodpct100	Yes	14.7	13.3	162.3
Ongoing programme (operational costs only)				
rc_mempct22_prodpct25	Yes	0.9	8.9	17.6
rc_mempct22_prodpct50	Yes	2.0	11.4	35.3
rc_mempct22_prodpct75	Yes	3.4	12.1	62.3
rc_mempct22_prodpct100	Yes	4.8	12.4	87.0
Ongoing programme, improved inclusion				
rc_mempct50_prodpct25	Yes	2.2	10.3	45.4
rc_mempct50_prodpct50	Yes	4.6	11.7	85.1
rc_mempct50_prodpct100	Yes	7.9	12.6	113.4
rc_mempct100_prodpct25	Yes	3.9	10.5	83.7
rc_mempct100_prodpct50	Yes	7.0	11.9	109.9
rc_mempct100_prodpct100	Yes	14.5	12.6	160.6
Full self-financing with a zero interest rate				
zi_mempct22_prodpct25	No	—	—	—
zi_mempct22_prodpct50	Yes	1.6	7.6	29.9
zi_mempct22_prodpct100	Yes	4.2	10.7	83.7
zi_mempct50_prodpct25	No	—	—	—
zi_mempct50_prodpct50	Yes	3.8	9.4	80.2
zi_mempct50_prodpct100	Yes	7.2	11.4	107.1
zi_mempct100_prodpct25	Yes	3.0	7.2	68.2
zi_mempct100_prodpct50	Yes	6.0	10.1	97.5
zi_mempct100_prodpct100	Yes	14.0	11.7	154.6
Full self-financing with a risk-free interest rate				
fi_mempct22_prodpct25	No	—	—	—
fi_mempct22_prodpct50	Yes	1.3	6.0	25.8
fi_mempct22_prodpct100	Yes	4.0	10.1	82.2
fi_mempct50_prodpct25	No	—	—	—
fi_mempct50_prodpct50	Yes	3.7	8.7	76.8
fi_mempct50_prodpct100	Yes	7.3	11.1	105.9
fi_mempct100_prodpct25	Yes	1.7	5.5	34.3
fi_mempct100_prodpct50	Yes	6.2	9.6	95.8
fi_mempct100_prodpct100	Yes	13.7	11.5	154.7
Full self-financing with a market interest rate				
mi_mempct22_prodpct25	No	—	—	—
mi_mempct22_prodpct50	No	—	—	—
mi_mempct22_prodpct75	Yes	2.1	7.7	33.8
mi_mempct22_prodpct100	Yes	3.8	9.3	78.0
mi_mempct50_prodpct25	No	—	—	—
mi_mempct50_prodpct50	Yes	2.9	7.7	60.8
mi_mempct50_prodpct75	Yes	4.9	9.5	88.1

Table 6
(*Continued*)

Scenario code	Arrangement sustainability[a]	Δ^b Household income, %	Member added value[c], %	Δ^b RPO profit, %
mi_mempct50_prodpct100	Yes	6.8	10.6	103.3
mi_mempct100_prodpct25	No	—	—	—
mi_mempct100_prodpct50	Yes	5.3	8.8	91.0
mi_mempct100_prodpct75	Yes	9.4	10.3	121.6
mi_mempct100_prodpct100	Yes	13.5	11.1	152.2

Note: Values not available when RPO certification was discontinued due to negative profitability.
[a]Yes if certification was sustained during the 15-period simulation and no otherwise;
[b]Relative difference compared with baseline scenario;
[c]Added value per unit of certified green coffee compared to baseline price of conventional coffee.

9–12% of conventional coffee price depending on the scenario. Therefore, agents are willing to bear the certification-related costs, which in this case are the individual and organisational operational costs of the certification. Simulated added value (Table 6) also increases with larger member inclusion and improvements in the share of certified coffee sold by the RPO.

Figure 5 displays the income effects of group certification over time, showing a modest aggregate impact of the current certification programme with 22% certified members and alternative shares of certified coffee (*mempct22–prodpct25, 50, 75, 100*). Even if the agents are able to certify 100% of their coffee sold through the RPO (*rc_mempct22_prodpct100*), the mean income is only 5% above the baseline. In contrast, the impact simulated for the complete certification scenario (100% membership, 100% of produce certified) is significantly higher, increasing by almost 15% compared with the baseline.

Table 7 reports the investment indicators for six of the certification scenarios, comparing those that most resemble the current certification scheme in Kibinge DC (only covering the operational costs of certification) with the fully self-financing scenarios (also servicing the initial investment costs at the market rate of interest). Both ongoing and self-financing options in Table 7 were simulated with the current member inclusion in the certification programme (22% of agents) and with an alternative 'improved' inclusion (50% of agents). In addition, we simulated the '100% scenario' for both programmes, where all of the agents are certified at the start of the simulation. In the '100% scenario,' there is no restriction on the amount of produce that the agents can certify, while in the other scenarios in Table 7, each agent can certify a maximum of 50% of its produce.

5. Discussion

5.1. Interpretation of results

At current certification levels (22% of members certified) and with only operational costs of certification covered by the RPO (all other costs funded by external donors), the RPO can distribute its fixed costs over sufficiently large volumes and pay higher

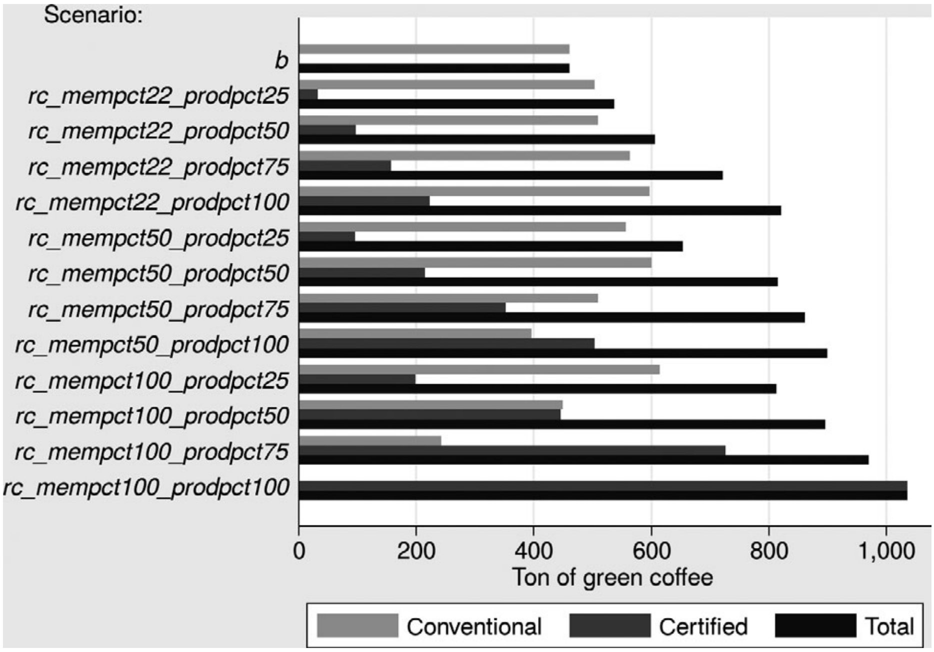

Figure 4. Simulated coffee sales of RPO with group certification
Note: Scenarios reflect the current financing scheme (operational costs only) with 22%, 50% or 100% of the members involved in certification and 25%, 50%, 75% or 100% of the produce permitted for certification.

coffee prices to its members. The added value of certification in our case study was found to be around 10% of the conventional coffee price, which is an encouraging result but much lower than in previous empirical studies that reported price premiums of up to 30% without explicitly considering the costs of group certification. However, if we drop the small project assumption and include the possible (but unknown) price effects of an increased RPO supply of VSS-certified coffee in Uganda, the added value would be further reduced.

Our simulations show that economic sustainability of group certification depends on increasing the membership of the DC, and increasing the share of their coffee delivered and sold as certified. This increase of certified coffee volumes in our simulations comes from higher levels of intensity in agent coffee production and from diversion of coffee sales away from middlemen to the RPO. In addition, our simulation results suggest that if the full costs of certification are reflected back to producers, certification becomes unprofitable. Without external donor support, current membership levels and certified coffee volumes are too low to maintain RPO group certification.

5.2. *Model limitations*

Our simulation model necessarily reflects the particular conditions of a single sub-county-level RPO. First, the Kibinge DC, with almost 2,000 members from 1,716 farming households, is a relatively large organisation. According to the IFPRI (2010) survey, other sub-county-level organisations in Uganda have 1,006 members on

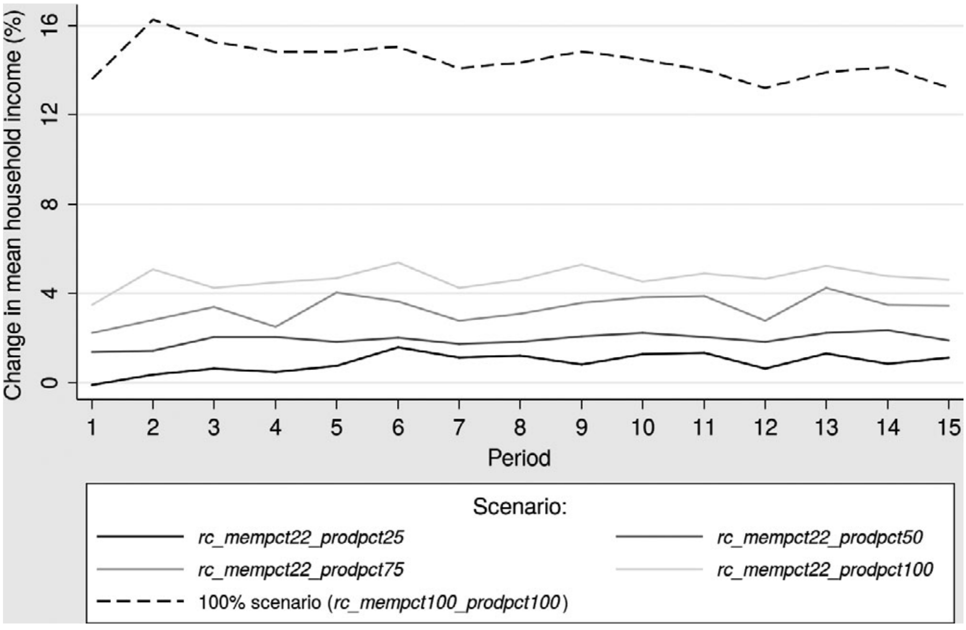

Figure 5. Simulated income effect of group certification
Note: Scenarios reflect situations with the current financing scheme (operational costs only), the current share of members involved in certification (22%) and 25%, 50%, 75% or 100% of the produce permitted for certification. Change of income is computed as the relative difference compared with the baseline scenario (no certification).

average and 550 as a median. In smaller organisations, UTZ group certification is expected to have even smaller income effects.

Second, compared with other RPOs in the country, Kibinge DC's business operations are well-organised (Latynskiy and Berger, 2016). A solid RPO infrastructure and management capacity will generally be a necessary condition for the successful implementation of group certification. Kibinge DC, therefore, represents the likely upper bound for positive certification effects that smaller and less efficient organisations can achieve in Uganda.

Third, all input and output prices except the 'internal' farm-gate price for member coffee were fixed in our model, ignoring possible price effects when more processed coffee is supplied on the Ugandan export market. Unlike the MPMAS simulation studies of Wossen and Berger (2015) in Ghana and Berger *et al.* (2016) in Ethiopia, we did not consider price volatility that might create both business opportunities and threats for smallholder farmers. Also for these reasons, the income effects simulated here are likely to be the upper bounds for what can be expected in reality.

Fourth, the project survey (IFPRI, 2010) covered only the households that were RPO members at the time of the survey, while data from other producers were not collected. Consequently, the simulation model could not include any non-member agents, and agent membership in the RPO was fixed during the simulation. Therefore, in the current implementation of the model, it was not possible to simulate potential spillover effects of certification attracting new members.

Table 7
Results of investment analysis for group certification

Scenario description	Scenario code	Sustain-ability[a]	EANB[b], mil. ugx	BCR[c]	IRR[d], %	Δ[e] Household income, %
Ongoing programme	*rc_mempct22_ prodpct50*	Yes	124	6.7	230	2.0
Ongoing programme, Improved inclusion	*rc_mempct50_ prodpct50*	Yes	294	9.7	294	4.6
Ongoing programme, 100% scenario	*rc_mempct100_ prodpct100*	Yes	956	16.8	648	14.5
Full self-financing, Current inclusion	*mi_mempct22_ prodpct50*	No	N/A	N/A	N/A	N/A
Full self-financing, Improved inclusion	*mi_mempct100_ prodpct50*	Yes	199	7.5	267	2.9
Full self-financing, 100% scenario	*mi_mempct100_ prodpct100*	Yes	911	16.8	646	13.5

Notes: [a]Yes if certification was sustained during the 15-period simulation and no otherwise; [b]Equivalent annual net benefit; [c]Benefit-cost ratio; [d]Internal rate of return; [e]Relative difference compared with baseline scenario.

6. Conclusions

This article shows that agent-based simulation can be applied to provide high-resolution quantitative data for the assessment of VSS certification, which are otherwise difficult if not impossible to obtain. Our model validation demonstrates that we are able to replicate the observed farm systems with an acceptable level of precision. Robustness tests and sensitivity analyses showed that the simulations of various treatments are both robust and consistent with expert judgement.

Generally, our simulations suggest that current donor investment in financing certification through RPOs is a useful development intervention in Uganda, as long as the RPO output prices for coffee are not negatively affected by increasing upstream supply (which could not be considered in our present study). Before broadly upscaling the results from this case study, development agencies should therefore commission further large-scale market studies on the possible effects of increased supply of certified Ugandan coffee on the world market and on the potential effects of better marketing (e.g. improved supply chain relationships and more efficient marketing chains).

Our simulation results, however, suggest that group certification of sustainably produced coffee has a small positive impact on the income of participating households. This result means that certification alone will not solve the challenge of improving farmer livelihoods in Uganda. The achievement of sustainable economic growth will require addressing not only marketing constraints but also production constraints such as the low use of improved varieties, the low intensity of fertiliser application and the lack of knowledge about appropriate agricultural practices (Dercon and Christiaensen, 2011; Asenso-Okyere and Jemaneh, 2012; Kostandini *et al.*, 2015). Moreover, farm productivity will have to grow substantially to overcompensate the possible price squeeze of increased farm output and raise smallholder incomes at least for some time before Cochrane's treadmill sets in.

Because we found that certification alone has a rather modest effect in terms of livelihood improvement, the next step for our research is using the developed model to identify policy packages that could support the commercialisation of smallholders in addition to coffee certification (such as input credits and improved crop varieties). Work is also ongoing to link MPMAS to Partial or General Equilibrium models as suggested in this journal by Berger and Troost (2014), so that large-scale supply effects on the coffee market can be considered adequately. We will also be conducting the simulations with the cost data from VSS certification schemes other than UTZ (i.e. Fairtrade, Organic), once the reliable cost data have been acquired.

To create a more holistic picture of the worldwide impact of VSS certifications on smallholder farmers, it is necessary to conduct consistent cross-country comparisons. The results communicated in this article show that such assessments should consider not only the price premiums but also the costs associated with establishing a certification programme and complying with its standards as well as possible market supply effects.

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